

Combustible Dust Training Program (C-DuST)



Overview

- According to a study by the Chemical Safety Board, Dust explosions are a serious problem in American industry. Over the last 28 years there have been approximately 3,500 combustible dust explosions, 281 of these have been major incidents resulting in the deaths of 119 workers and another 718 workers sustained injuries.
- There were 13 reported agricultural dust explosions in the United States in 2005 resulting in 2 fatalities and 11 injuries.

Goal

- To improve the safety of workers in environments where combustible dusts may be encountered by increasing employee awareness of this hazard and by demonstrating how the hazard can be recognized and addressed in their workplace.

Enabling Learning Objectives

- Identify the elements necessary for dust to explode.
- Explain how to prevent dust from reaching combustible levels.
- Describe the difference between primary and secondary dust explosions.

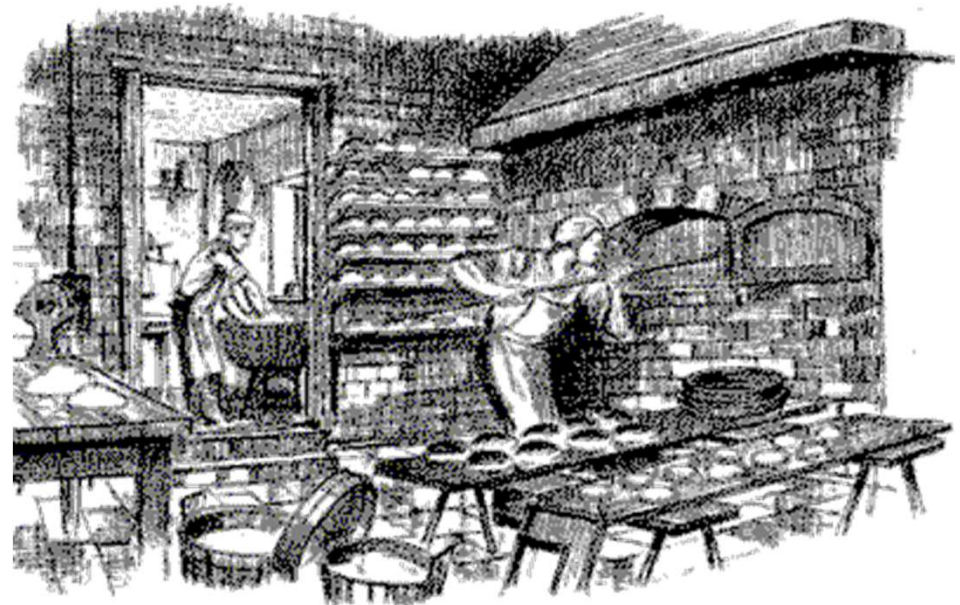
Terminal Learning Objective

Program participants will understand:

- Combustible dust danger in their industry.
- The Dust, Fire, and Explosive Pentagon.
- The methods to prevent or mitigate the effects of combustible dust explosion and resulting fire.

Introduction

- The first documented dust explosion occurred in a Turin, Italy, bakery in 1785.
 - The explosion was caused by the ignition of flour dust by a lamp in a bakery storeroom.
 - It led to the realization that grain dust is a highly explosive substance that must be handled carefully.



Introduction

A Chemical Safety Board Study Shows:

- From 1996 to 2005, a total of 106 explosions resulted in 16 fatalities and 126 injuries, at an estimated cost of \$162.8 million in damages to the facilities.
- In 2005, there were 13 grain dust explosions reported in the US.

A RARE EVENT

But catastrophic when it happens!

Background

Organic Dust Fires and Explosions:

- Massachusetts
(3 killed, 9 injured)
- North Carolina
(6 killed, 38 injured)
- Kentucky
(7 killed, 37 injured)



Metal Dust Fire and Explosion: Indiana (1 killed, 1 injured)

Organic Dust Fire and Explosion Massachusetts

Fire in a foundry shell molding machine:

- Caused a primary explosion in **ducts containing heavy deposits of Phenol formaldehyde resin dust**.
- Resulted in
 - a **dust cloud** from ledge dust deposits outside the ducts and
 - an **explosion in the plant area**.



Organic Dust Fire and Explosion Massachusetts

Causal factors

- **Housekeeping** to control dust accumulations;
- **Ventilation** system design;
- **Maintenance** of ovens; and,
- **Equipment safety** devices.



Organic Dust Fire and Explosion: North Carolina

Combustible **polyethylene dust accumulated above suspended ceilings** at pharmaceutical plant

- A fire at the plant caused dust to be dispersed and explode in the ceiling space
- 6 were killed, 38 injured
- Plant and nearby buildings were severely damaged



Experience in the Grain Handling Industry

In the late 1970s, grain dust explosions left 59 people dead and 49 injured.



Experience in the Grain Handling Industry

In 1987, OSHA promulgated the Grain Handling Facilities standard (29 CFR 1910.272) still in effect.





Imperial Sugar Company, Port Wentworth GA.
Explosion and Fire
Feb. 7, 2008
13 Dead and Numerous serious injuries



Dust Explosions

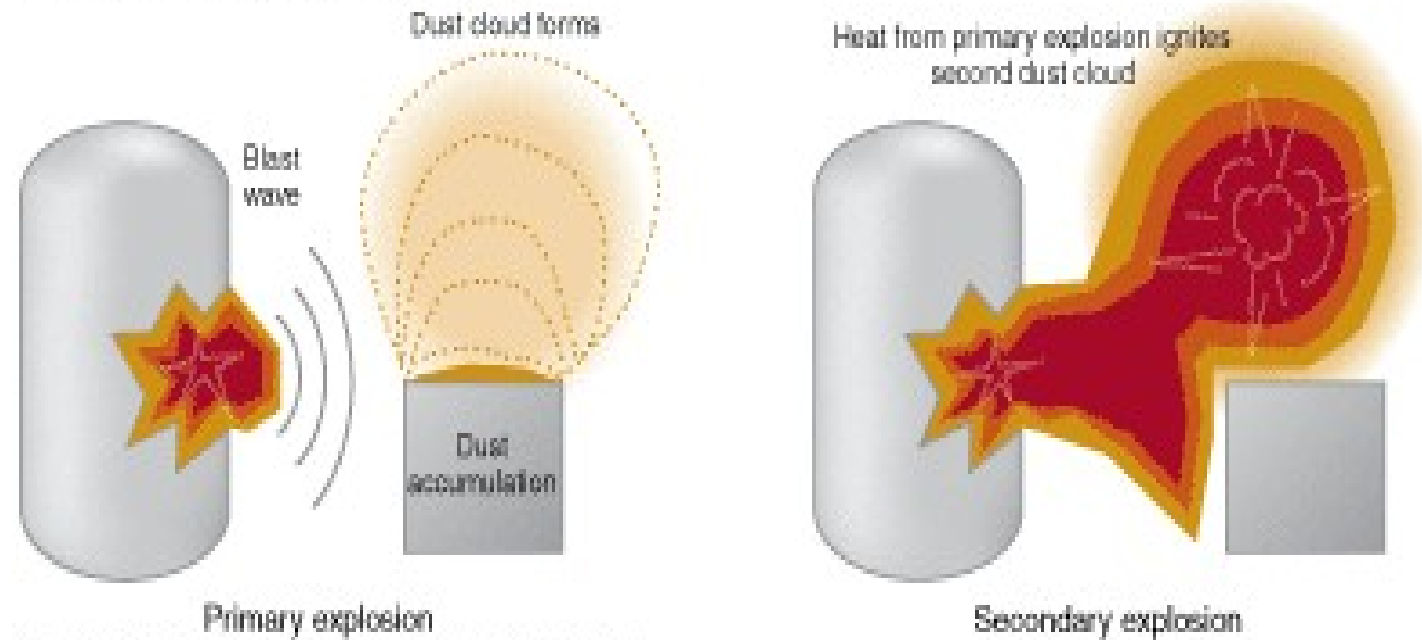
An initial (primary) explosion in processing equipment or in an area where fugitive dust has accumulated may shake loose more accumulated dust, Or damage a containment system (such as a duct, vessel, or collector).



- The additional dust dispersed into the air may cause **one or more secondary explosions.**
- These can be **far more destructive** than a primary explosion

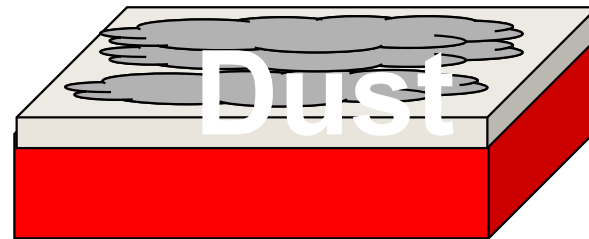
CASCADING EXPLOSIONS

Cascading explosions



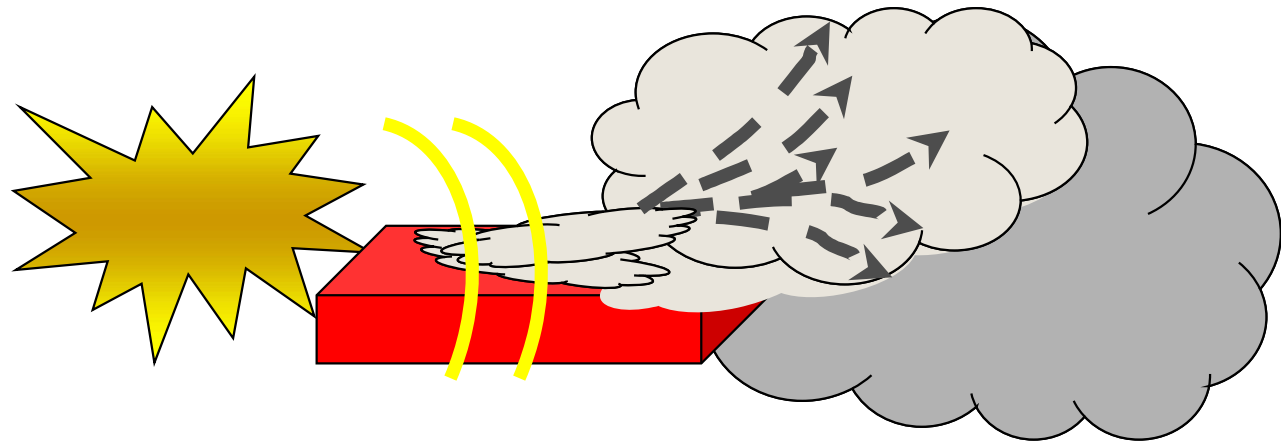
Source: Control Engineering with information from Pepperl+Fuchs

Dust explosion in a work area

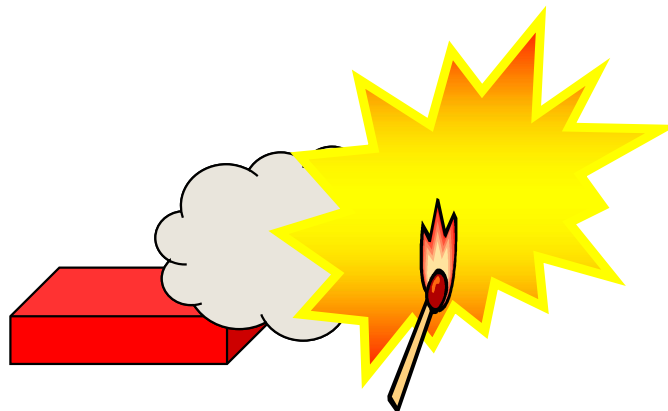


Dust settles on flat surfaces

Some event disturbs the settled dust into a cloud



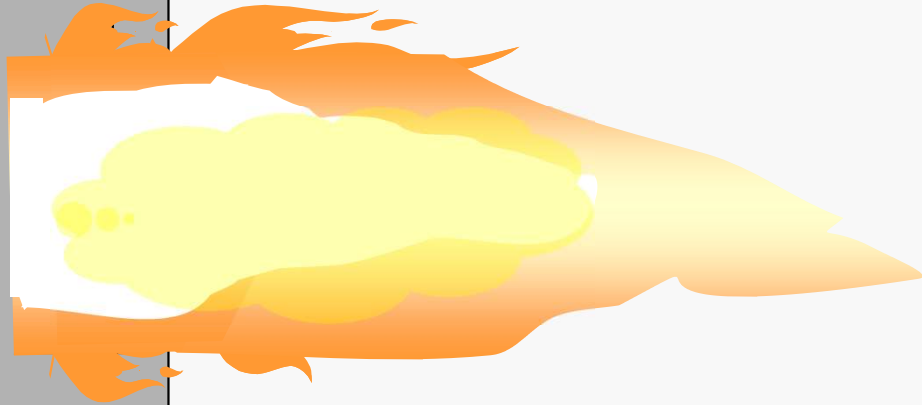
Adapted from CSB



Dust cloud is ignited and explodes

Dust explosion in equipment

**Dust
collector
venting
flame jet**



Dust explosion in equipment



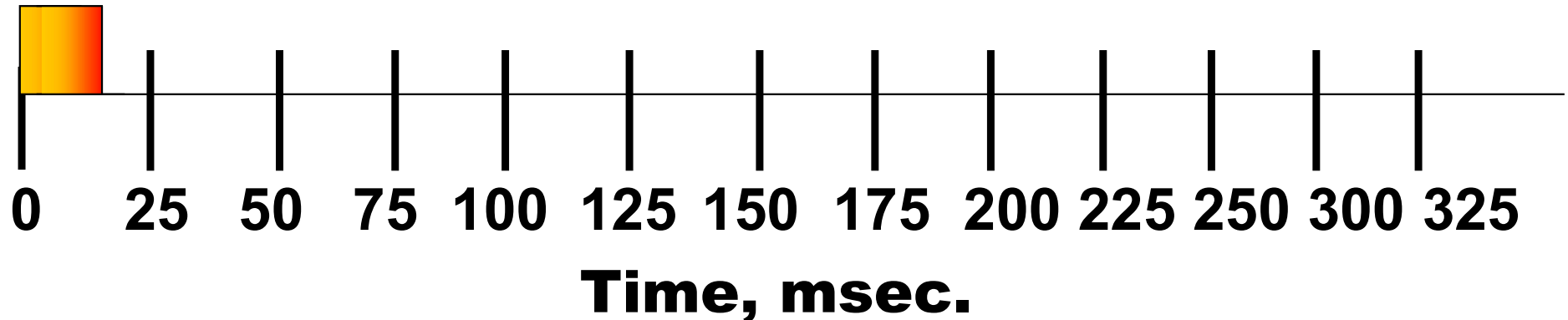
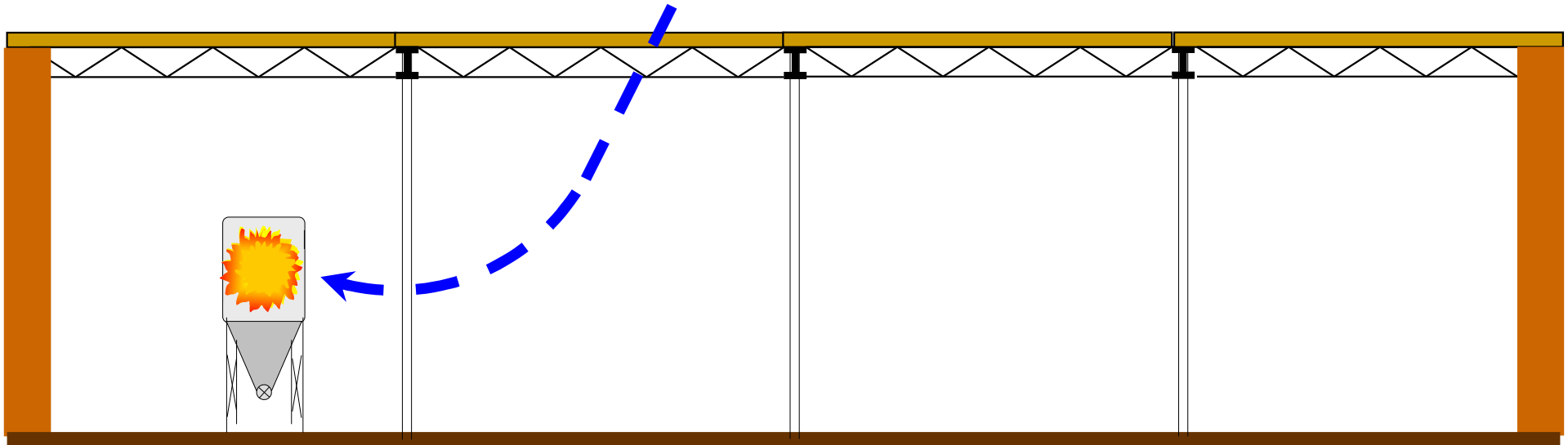
With dispersal
and ignition of 2 kg dust
by the flame jet

A timeline

The following nine slides depict a timeline for a dust explosion and the results of that explosion.

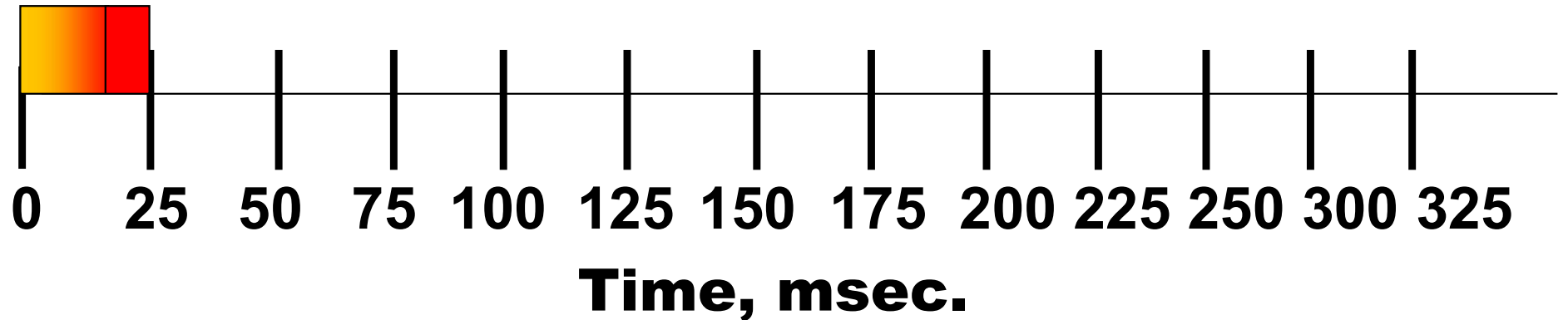
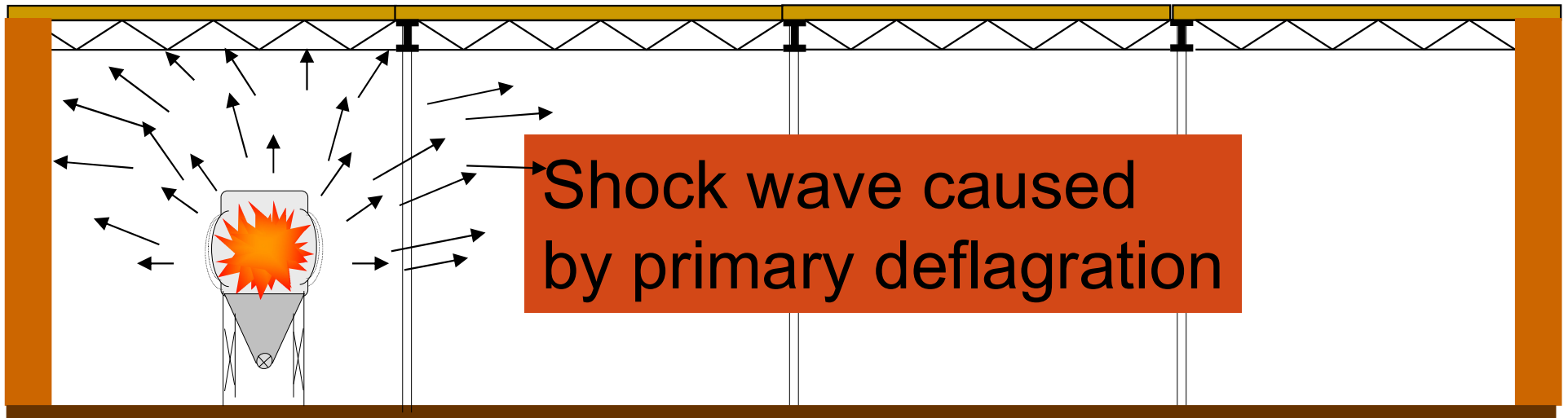
A Dust Explosion Event

Primary deflagration inside process equipment



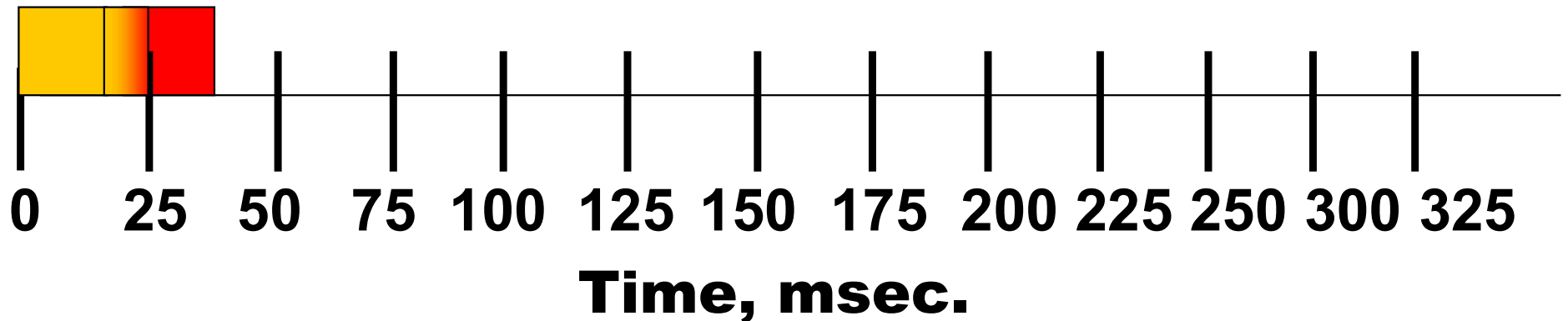
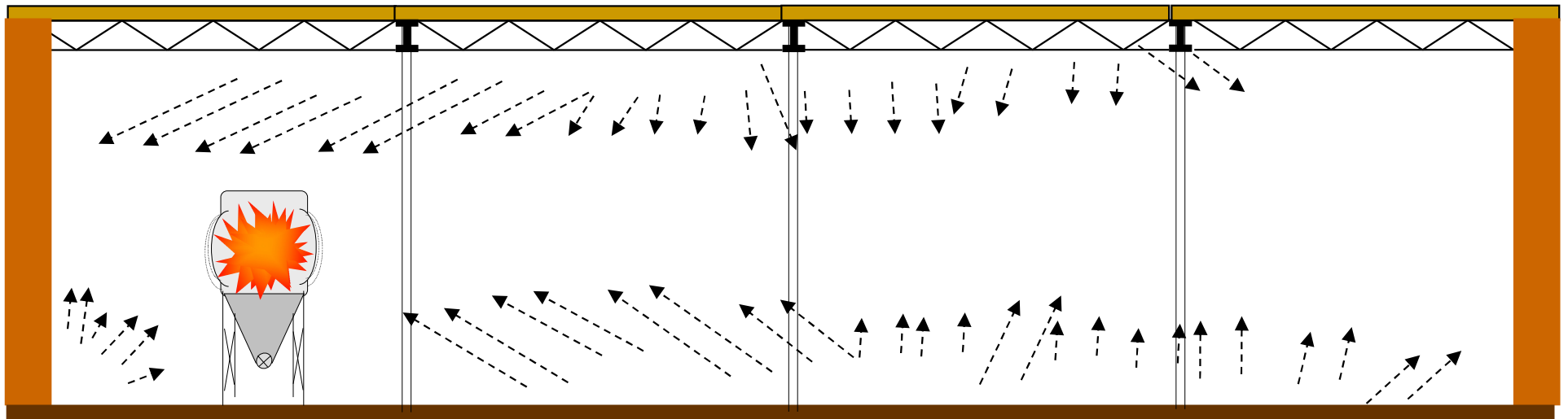
(Timing of actual events may vary)

A Dust Explosion Event



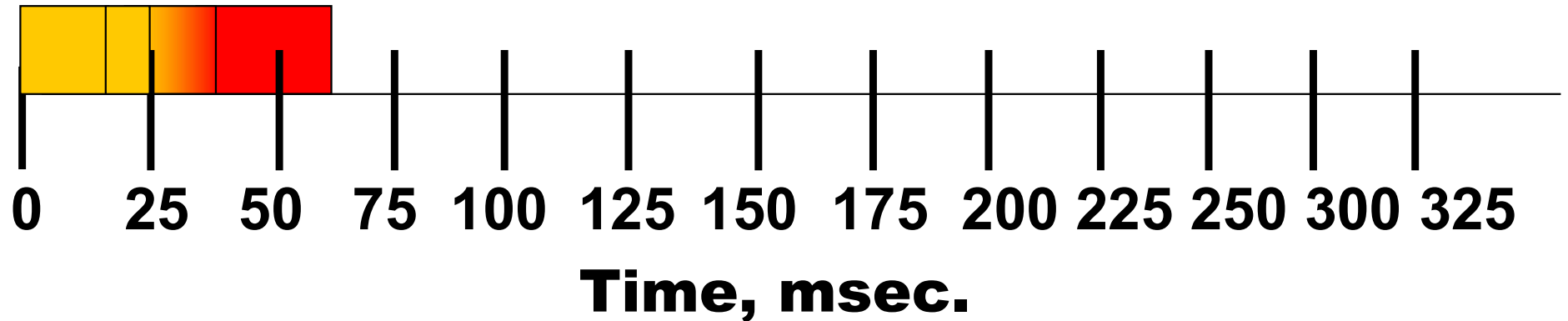
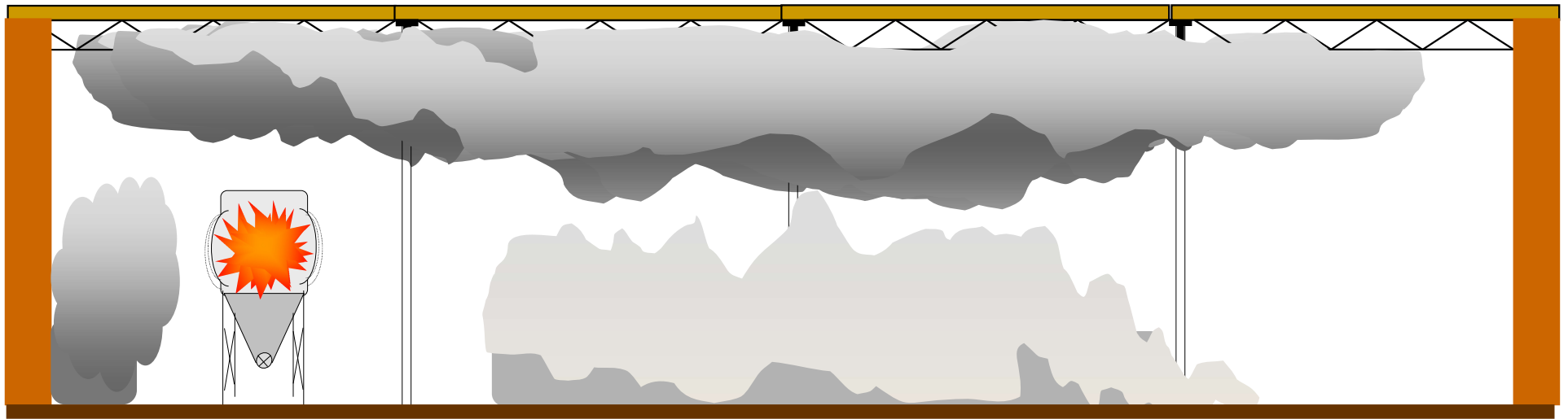
A Dust Explosion Event

Shock waves reflected by surfaces within the building cause accumulated dust to go into suspension



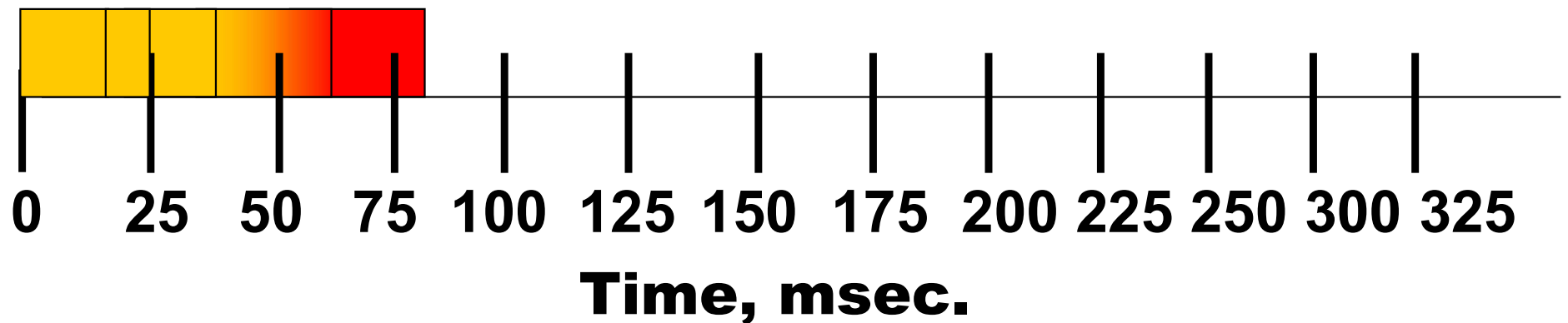
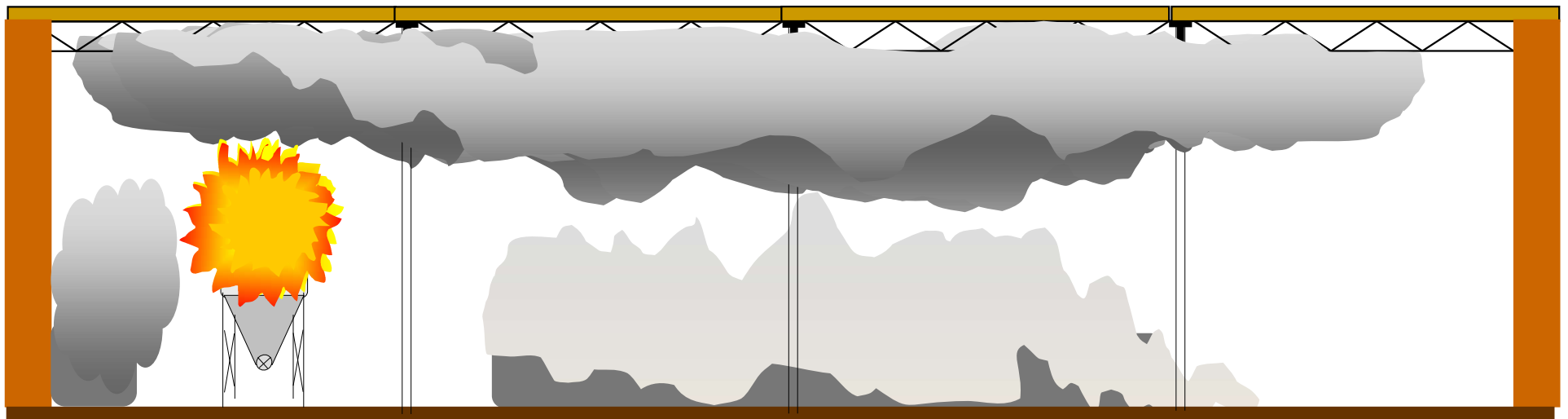
A Dust Explosion Event

Dust clouds thrown in the air by the shock waves



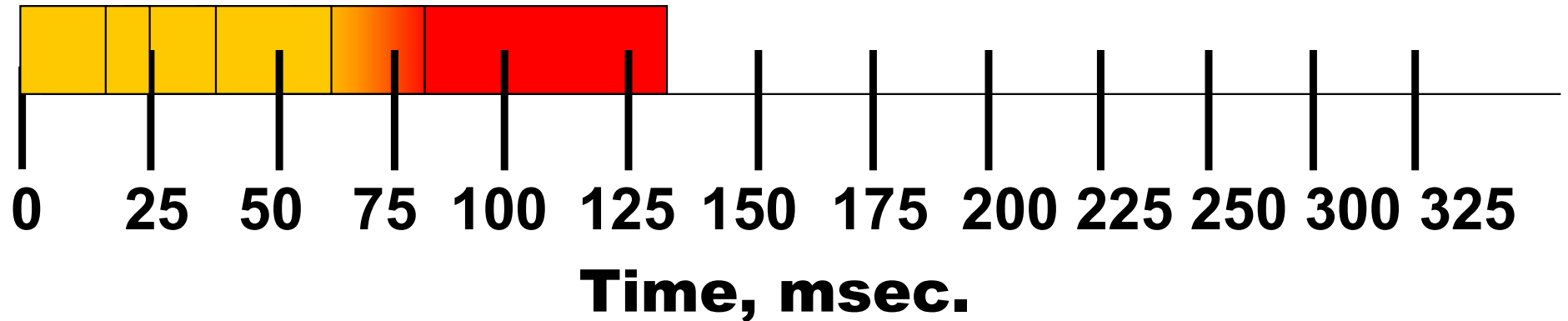
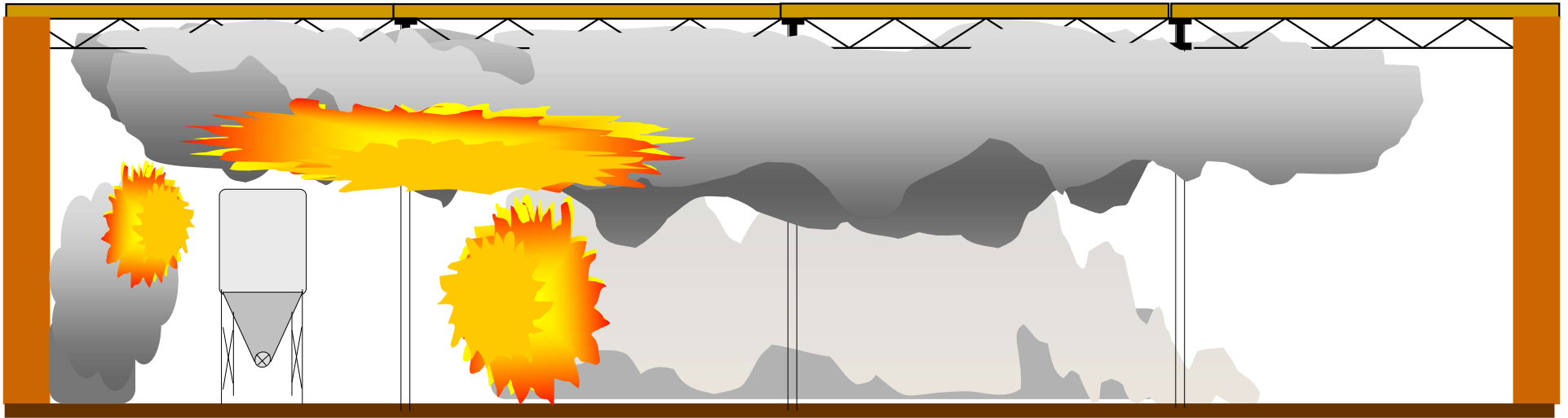
A Dust Explosion Event

Primary deflagration breaks out of the equipment enclosure - creating a source of ignition



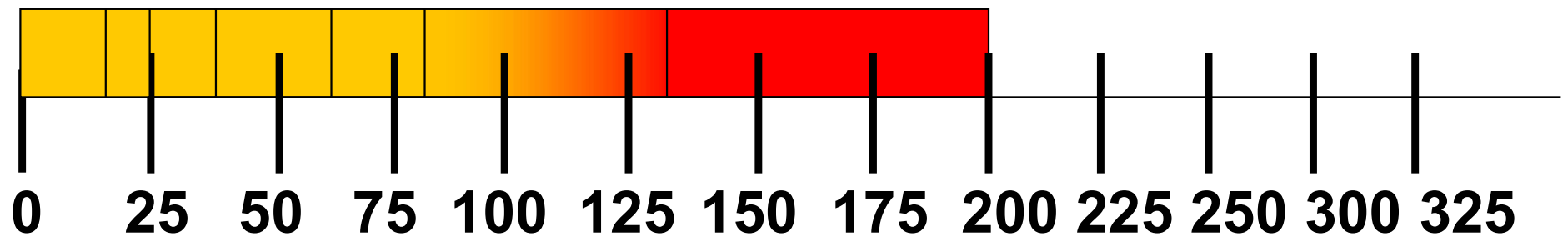
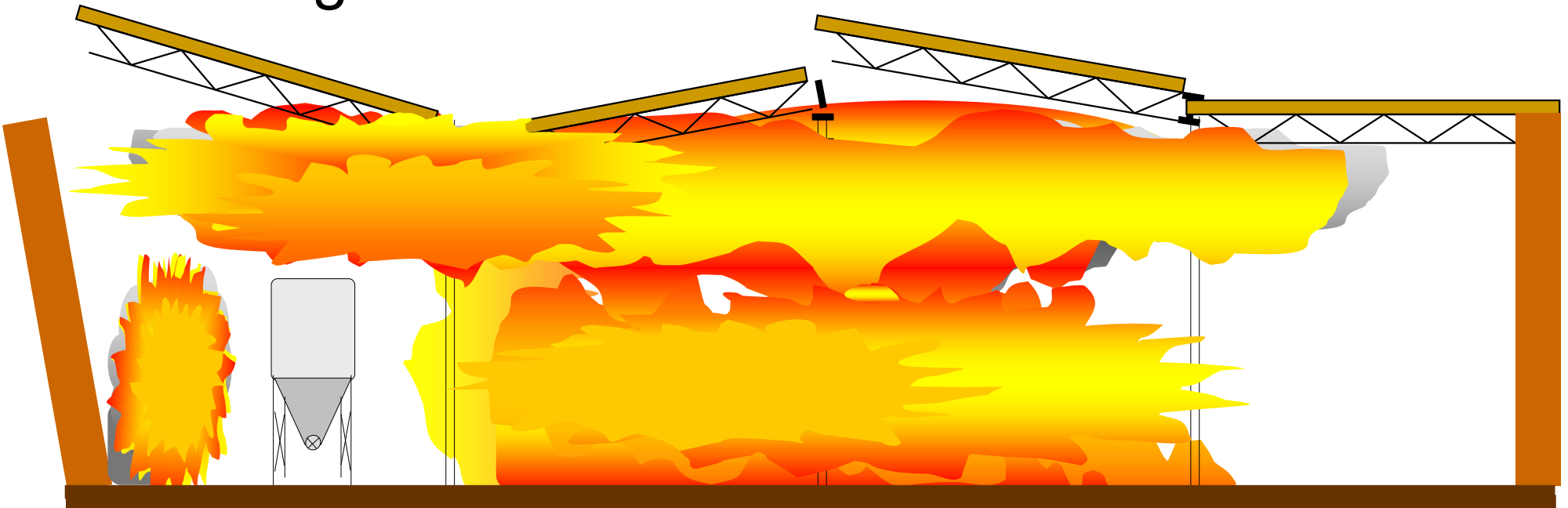
A Dust Explosion Event

Secondary deflagration ignited

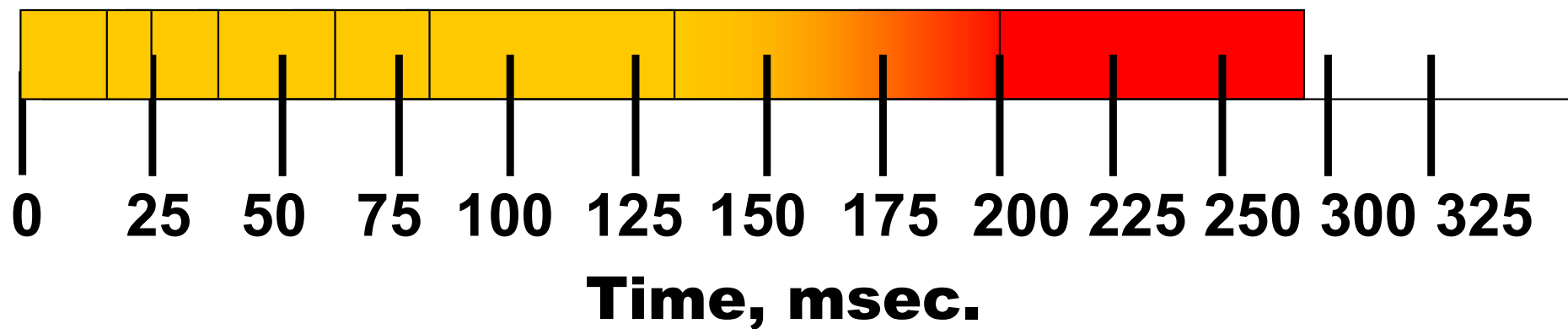
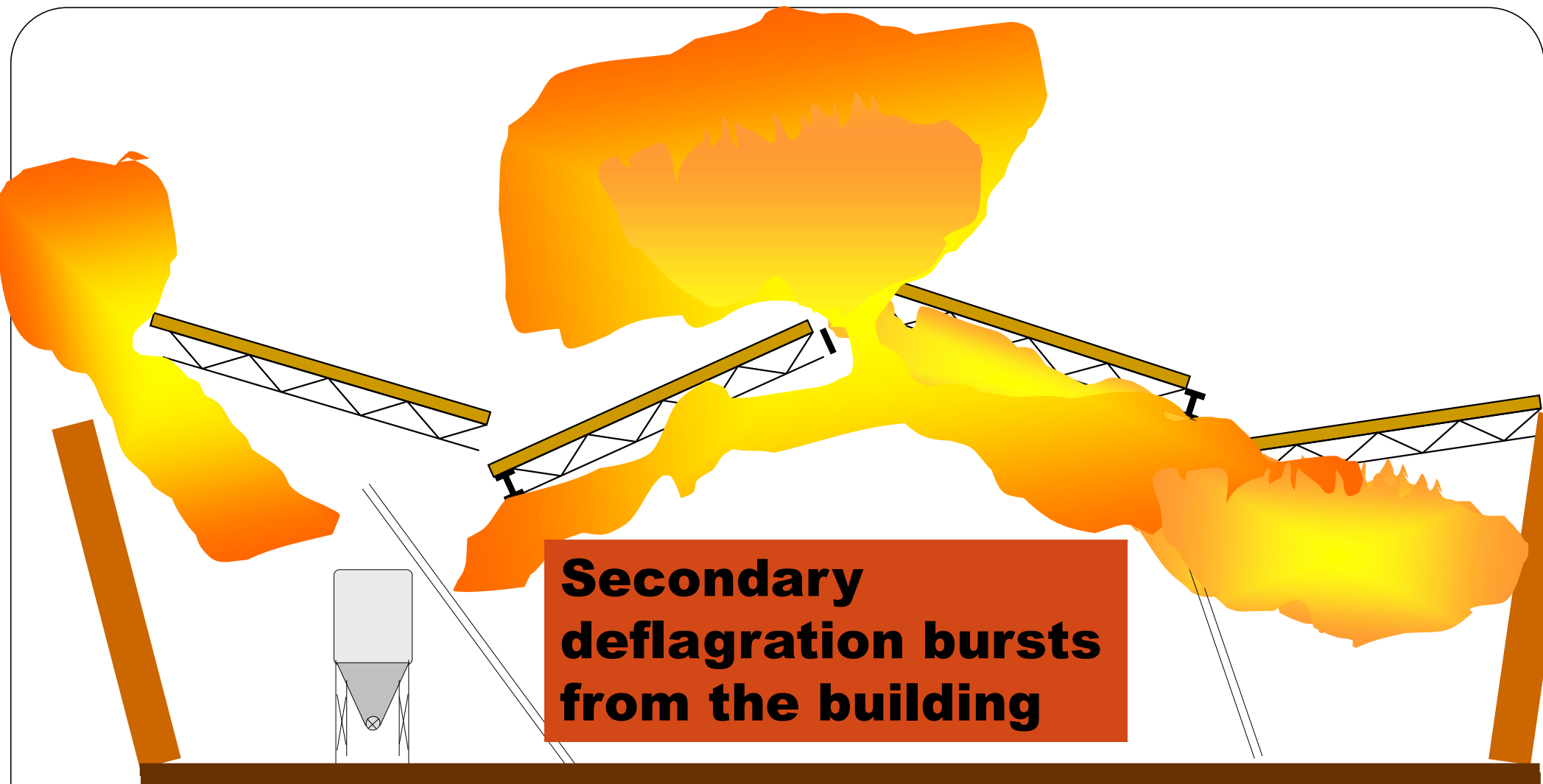


A Dust Explosion Event

Secondary Deflagration is propagated through the dust clouds

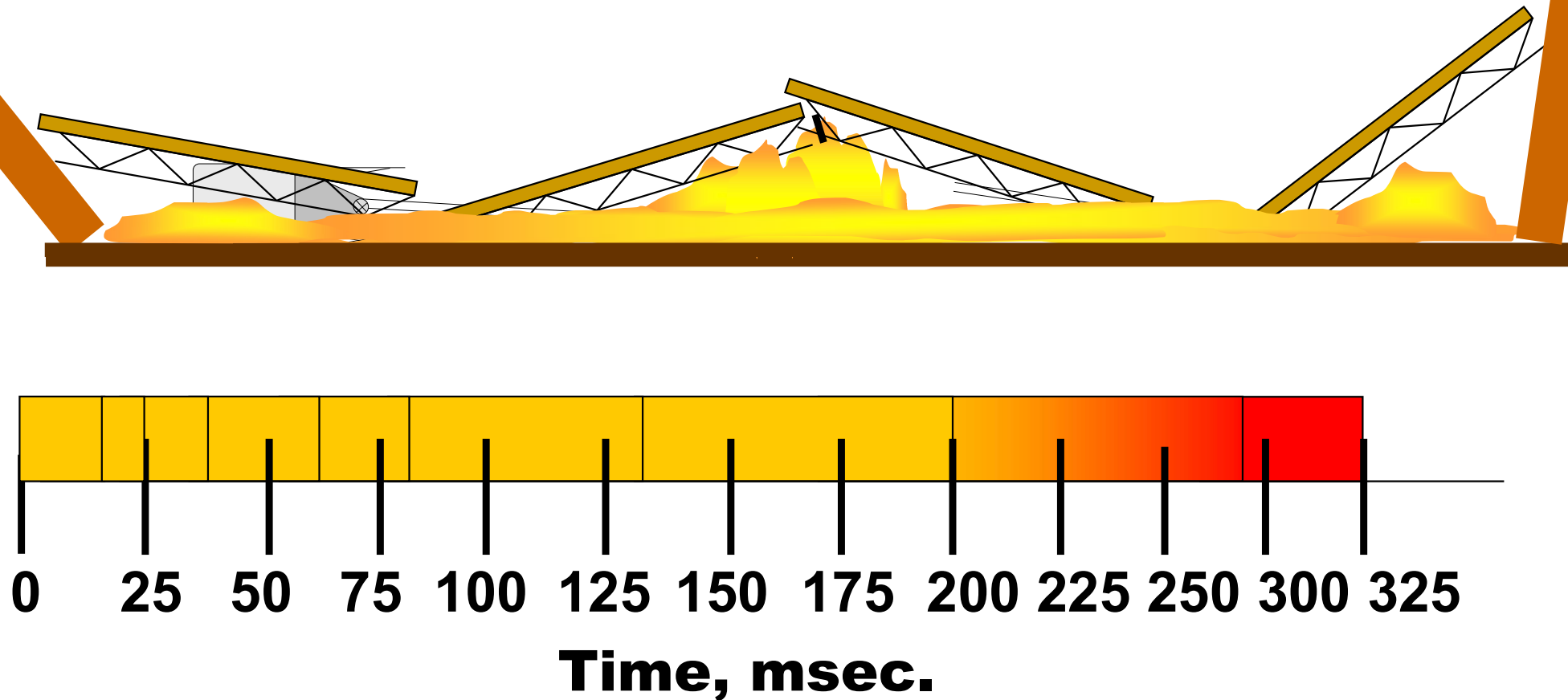


Time, msec.

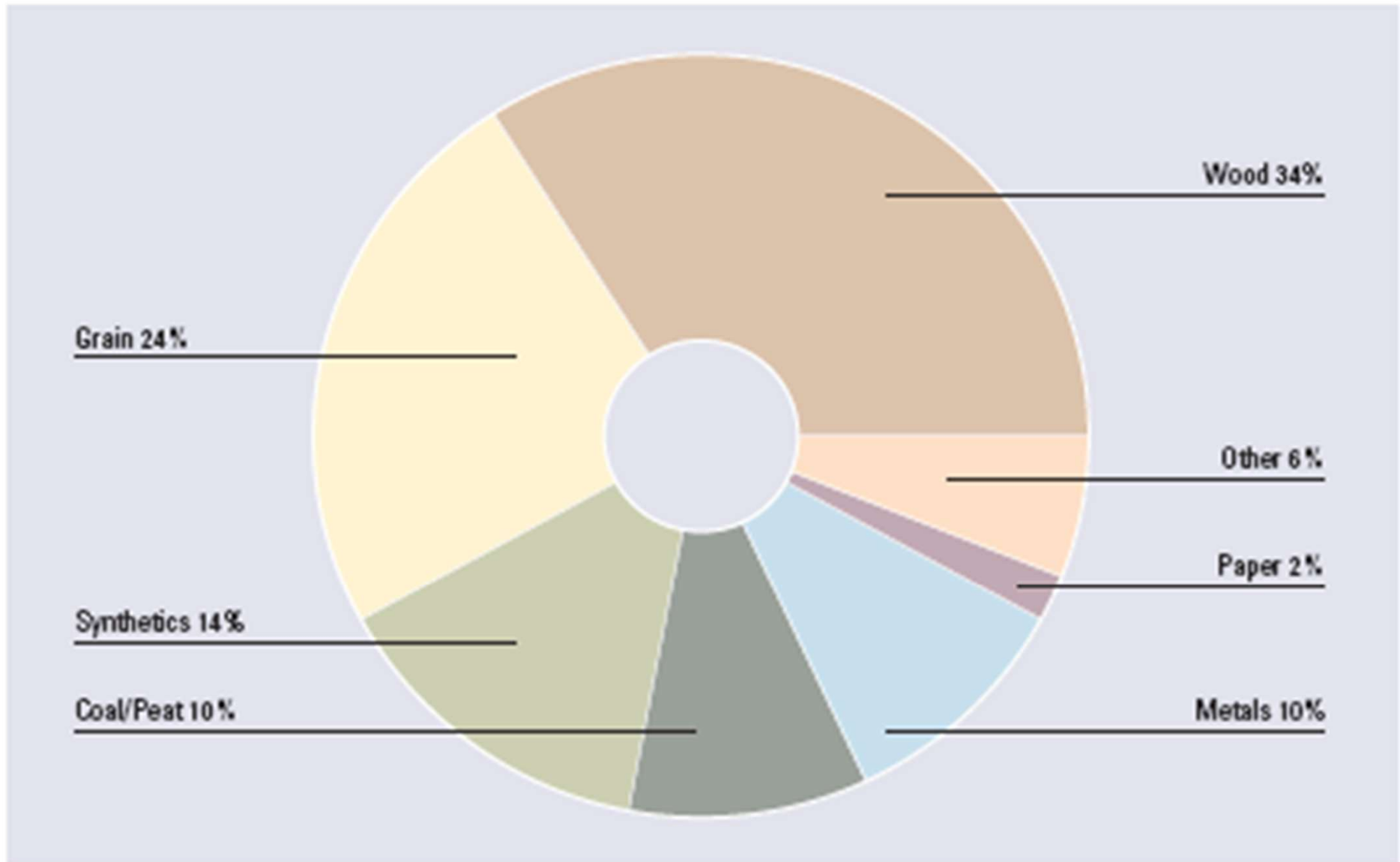


A Dust Explosion Event

Collapsed building with remaining fires



Types of Dusts Involved in Explosions



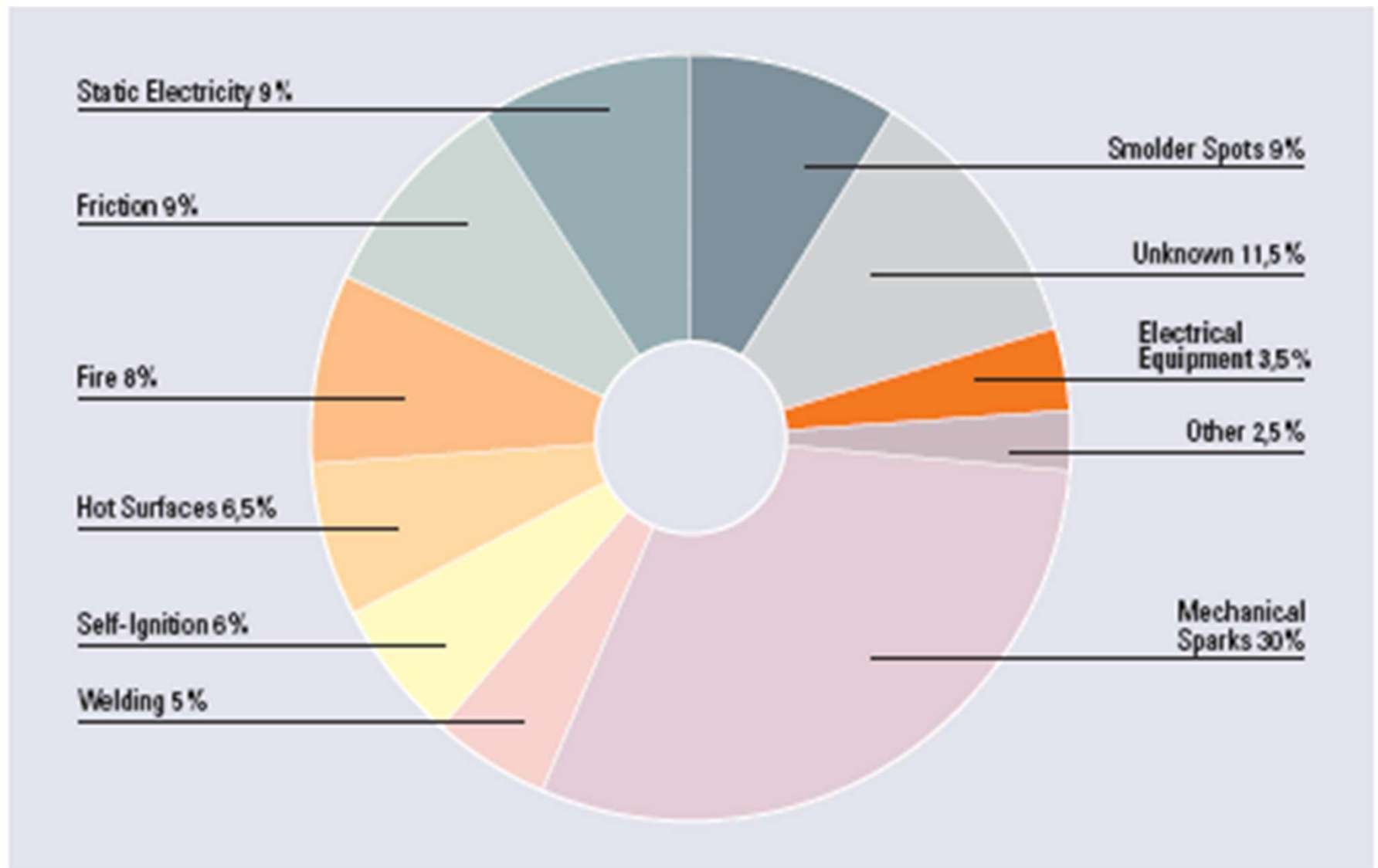
Required Conditions for an Explosion

- The dust must be combustible and fine enough to be airborne.
- The dust cloud must beat the Minimum Explosive Concentration (MEC) for that Particular dust.
- There must be sufficient oxygen in the atmosphere to support and sustain combustion.
- There must be a source of ignition.
- The dust must be confined.
- The dust must be dry.



Dust Particle

Ignition Sources



Explosive Limits

- The Minimum Explosive Concentration (MEC) for grain dust, grain flour, or ground feed ingredients varies according to the particle size and energy:
 - Smaller particles are more powerful
 - Caloric value of the product
- Corn starch is considered one of the more volatile and powerful grain products.
- As the size of the particle decreases the risk of a deflagration or explosion increases.

Dust Combustibility



Combustible dust per NFPA 654

- Prior to 2006 - “Any **finely divided solid material that is 420 microns or smaller** in diameter (material passing a U.S. No. 40 Standard Sieve) and presents a fire or explosion hazard when dispersed and ignited in air.”
- 2006 Edition – A combustible particulate solid that **presents a fire or deflagration hazard** when suspended in air or some other oxidizing medium over a range of concentrations, regardless of particle size or shape.

Facility Dust Hazard Assessment

Combustible dust explosion hazard may exist in a variety of industries

- Food (e.g., candy, starch, flour, feed)
- Plastics
- Wood
- Rubber
- Furniture
- Textiles
- Pesticides
- Pharmaceuticals

- Dyes
- Coal
- Metals (e.g., aluminum, chromium, iron, magnesium, and zinc)
- Fossil fuel power generation

The Prevalence of Dust

- Examples of materials that have historically caused dust explosions include:
 - Cosmetics
 - Coal
 - Dyes
 - Grain and other dry foods
 - Metal
 - Pharmaceuticals
 - Plastic and rubber
 - Printer toner
 - Soaps
 - Textiles
 - Wood and paper

Housekeeping

- **NFPA 654 and FM Global Data Sheet 7-76** are referenced.
- **Clean immediately** whenever a dust layer of **1/32-inch thickness** accumulates
 - over a surface area of at least **5% of the floor** area of the facility or any given room.
 - **not to exceed 1,000 ft²**



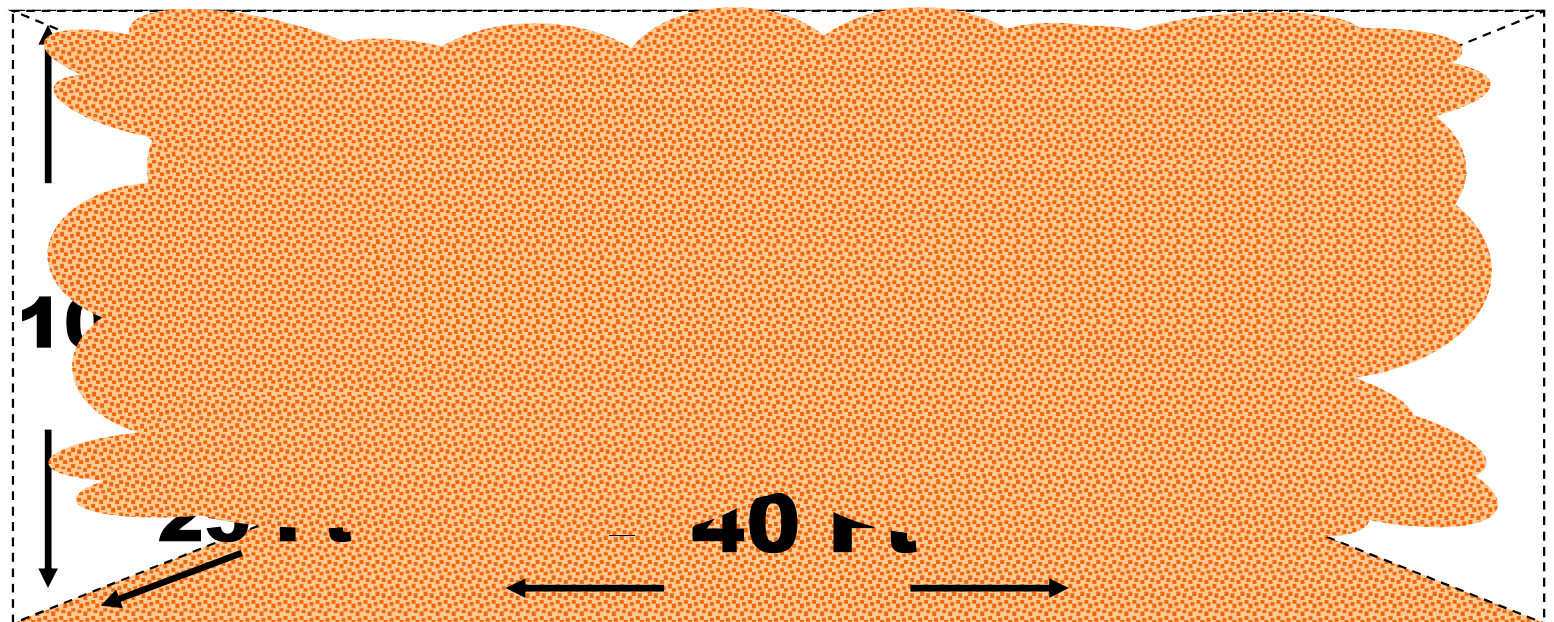
Sampling coal dust

Housekeeping

An idealized approach based on:

- **Uniformity** of the dust layer
- **Bulk density of 75 lb/ ft³,**
- **Dust concentration of 0.35oz/ ft³,** and
- Dust cloud height of 10 ft.

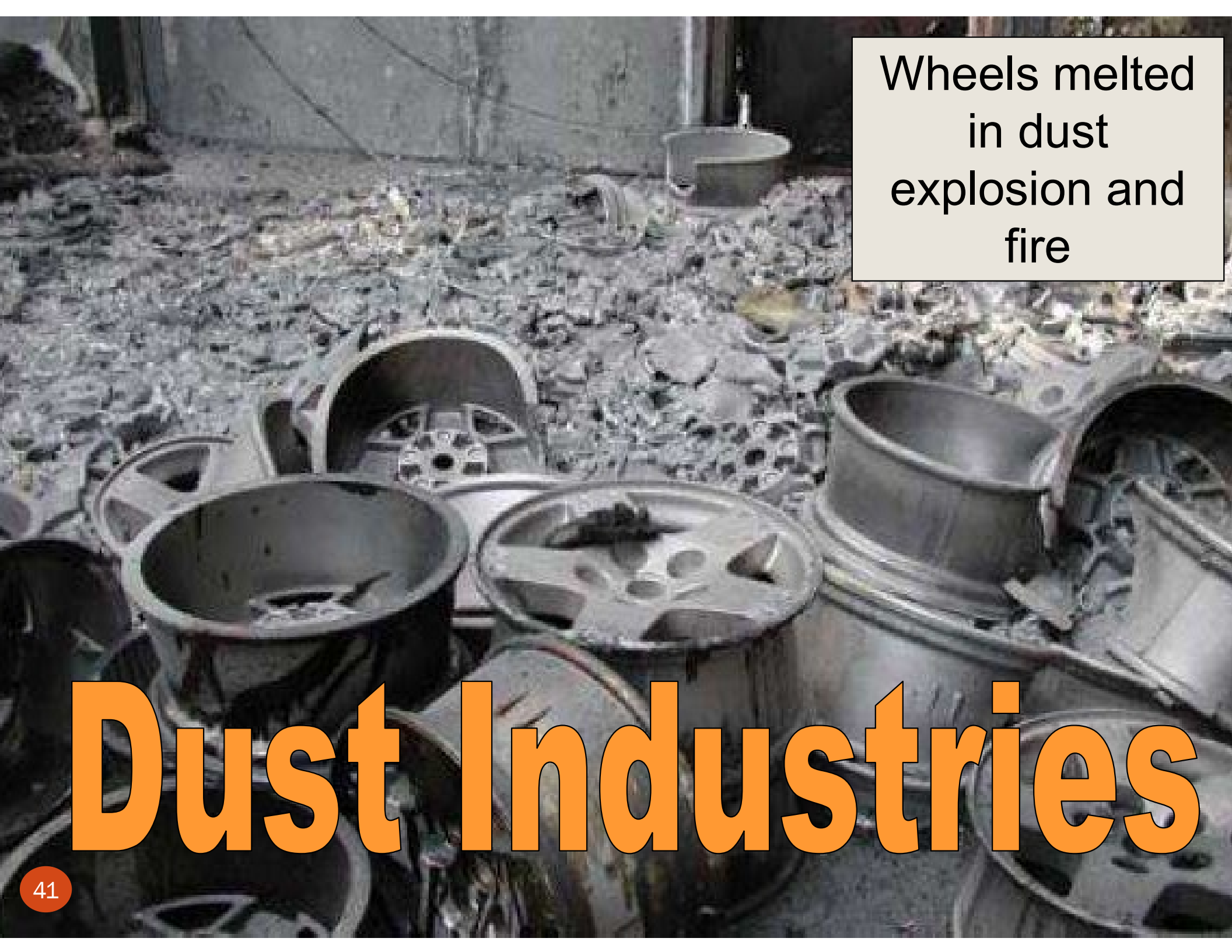
5% of
20,000 ft²
building



Where Do Dust Explosions Occur?

- Dust explosions, for grain, usually occur at transfer points as in bucket elevators or enclosed conveyors.
- In 1997, 50 percent of primary explosions occurred in elevator legs.
- Accumulation of dust in suspended ceilings
- Cyclone collectors
- Electrostatic collectors
- Holding bins





Wheels melted
in dust
explosion and
fire

Dust Industries

Industry With Dust

Corn Milling, Wet

Establishments primarily engaged in milling corn or sorghum grain (milo)

Electric Generation

Transmission, and/or distribution of electric energy

Flour and Other Grain Mill Products

Except rice

For exact description of SICs see:

http://www.osha.gov/pls/imis/sicsearch.html?p_sic=3999&p_search=

Industry with Dust

Reconstituted Wood Products

Hardboard, particleboard, insulation board, (and many similar products)

Chemicals and Chemical Preparations

NOC fatty acids, essential oils, gelatin (except vegetable), many other materials

Prepared Foods,

Various food items – dry, powdered foods

Electroplating,

Plating, Polishing, Anodizing, and Coloring (polishing and tumbling)

Industry with Dust

Pharmaceutical Preparations

Wood Products,

Sawmills and Planing Mills,

Cane Sugar Refining

Beet Sugar manufacturing

Mechanical Rubber Goods

Molded, Extruded, and Lathe-Cut

Motor Vehicle Parts and Accessories –

Numerous items including wheels and
transmission housings

Industry with Dust

Crop preparation for market except cotton gins
(cleaning, shelling, delinting)

Dry bakery products – cookies, crackers,
pretzels and similar

Flavoring extracts, syrups, powders and
related

Fabric mills, broadwoven manmade fibers and
silk (weaving fabrics >12 inches wide)

Fabric finishers, broadwoven manmade fibers
and silk (includes napping, sueding, teaseling)

Industry with Dust

Textile goods (many materials including waste, kapok, felt, recovered fiber)

Millwork

Wood kitchen cabinets

Structural wood members

Prefabricated wood buildings and components

Wood household furniture, except upholstered

Industry with Dust

Window blinds and shades and drapery hardware

Industrial inorganic chemicals

Plastics, synthetic resins, and elastomers (nonvulcanizable)

Cellulosic manmade fibers

Soap and detergents, except specialty cleaners

Paints, varnishes, lacquers, enamels, and allied products

Industry with Dust

Manufacturing industries NOC (includes many products e.g.: matches; candles; lamp shades; feathers; artificial trees and flowers)

Farm product warehousing and storage

Sanitary treatment facilities

Refuse systems

Scrap and waste materials

Plastic materials and basic forms and shapes

Explosion Safeguards

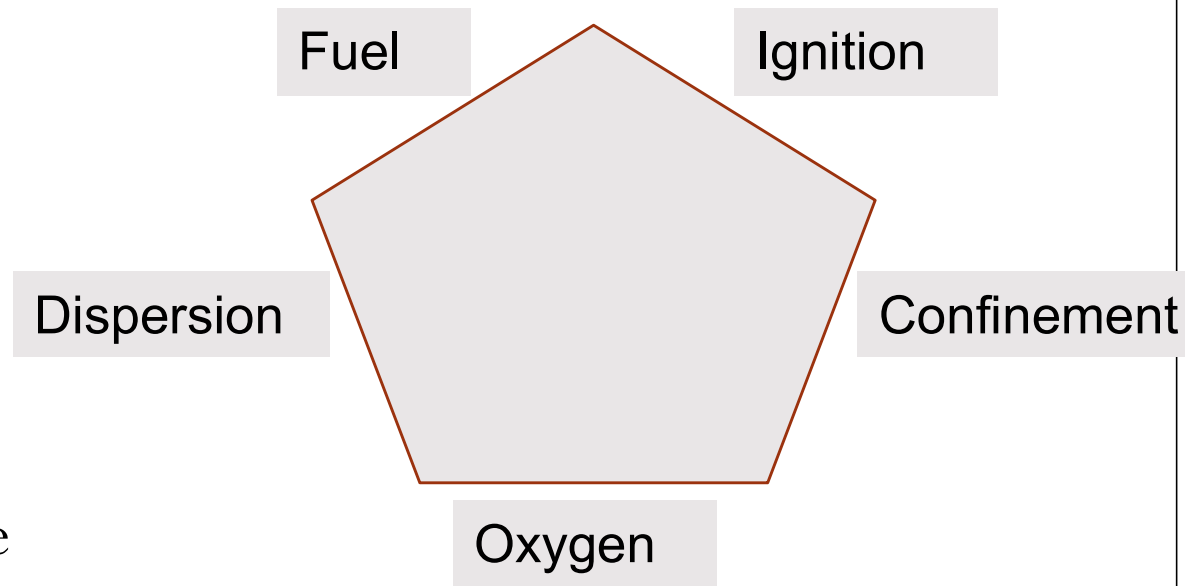
- Fire prevention and protection
- Housekeeping
- Dust control



Fire Prevention and Control

- Policies, practices and procedures designed to keep the conditions necessary for a fire from coming together (explosive pentagon)

- Fuel (dust)
 - Dust is dry
 - Dust is at MEC
- Oxygen
- Ignition source
- Confined or enclosed space
- Mixing of fuel and oxygen



Explosive Pentagon

Fire Prevention and Control

- Hot work permits
- Lockout/tagout policies
- Design specifications for storage of flammable materials
- Severity reduction policies, practices and procedures designed to minimize the spread of fire
- Emergency plans
- Alarm systems

Fire Prevention and Control

- Portable fire extinguishers
- Cleanup policies, practices and procedures designed to return the affected area to an operational level
- First aid
- Recharging portable extinguishers
- Removal of debris to an appropriate waste site
- Equipment and facility repair

Housekeeping

- A crucial key to the reduction of fires and explosions is housekeeping.
- Housekeeping relates to hazards in addition to fires and explosions.
- Research has shown that facilities that are well maintained experience fewer fires, explosions and other accidents.

Dust Control

NFPA 654 – contains comprehensive guidance

Some of its recommendations:

- **Minimize the escape** of dust from process equipment or ventilation systems;(fugitive dust).
- **Use dust collection** systems and filters.
- Utilize **surfaces that minimize dust accumulation** and facilitate cleaning.

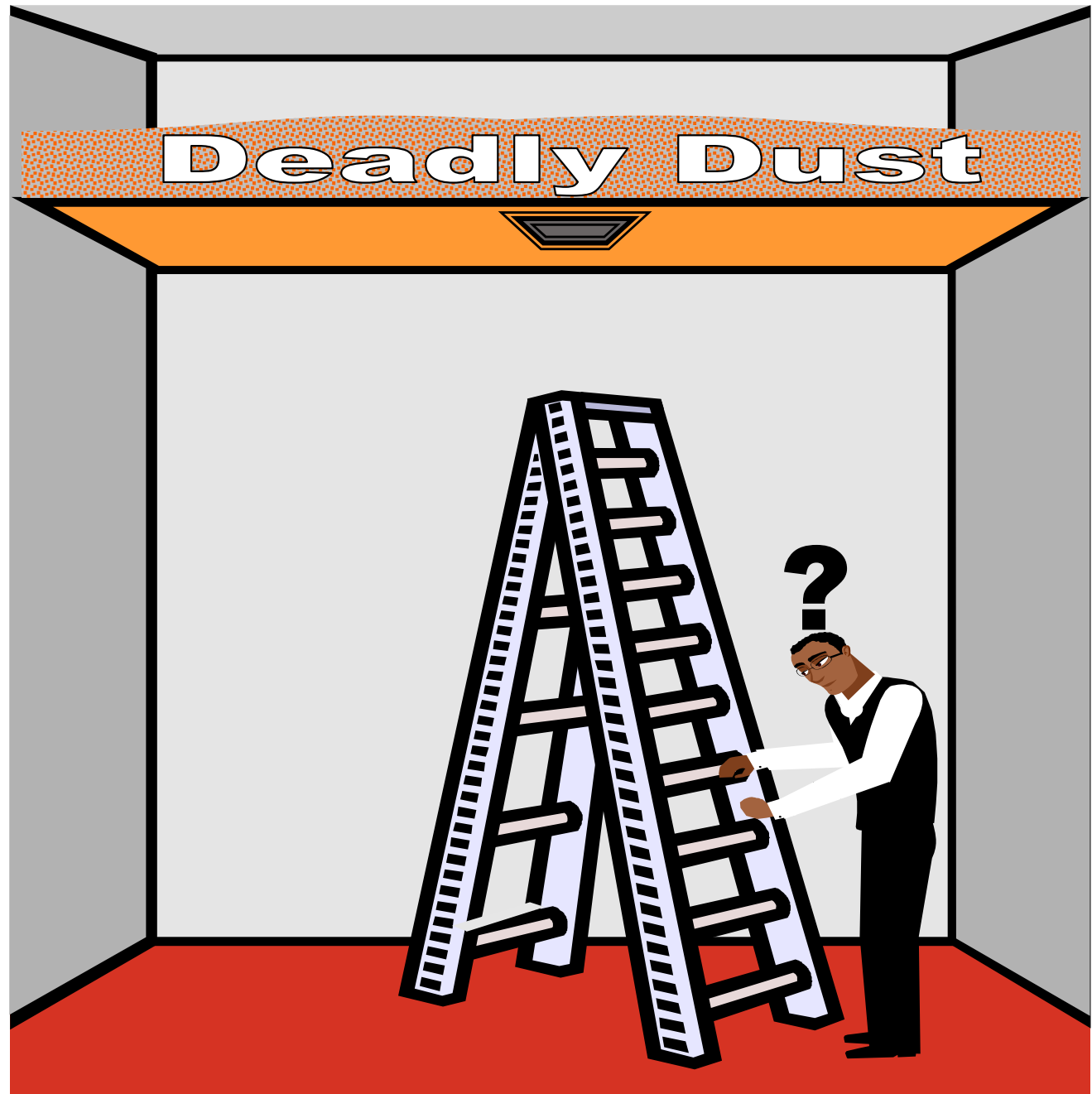
Spots are not raindrops



Dust Control

NFPA 654 – guidance

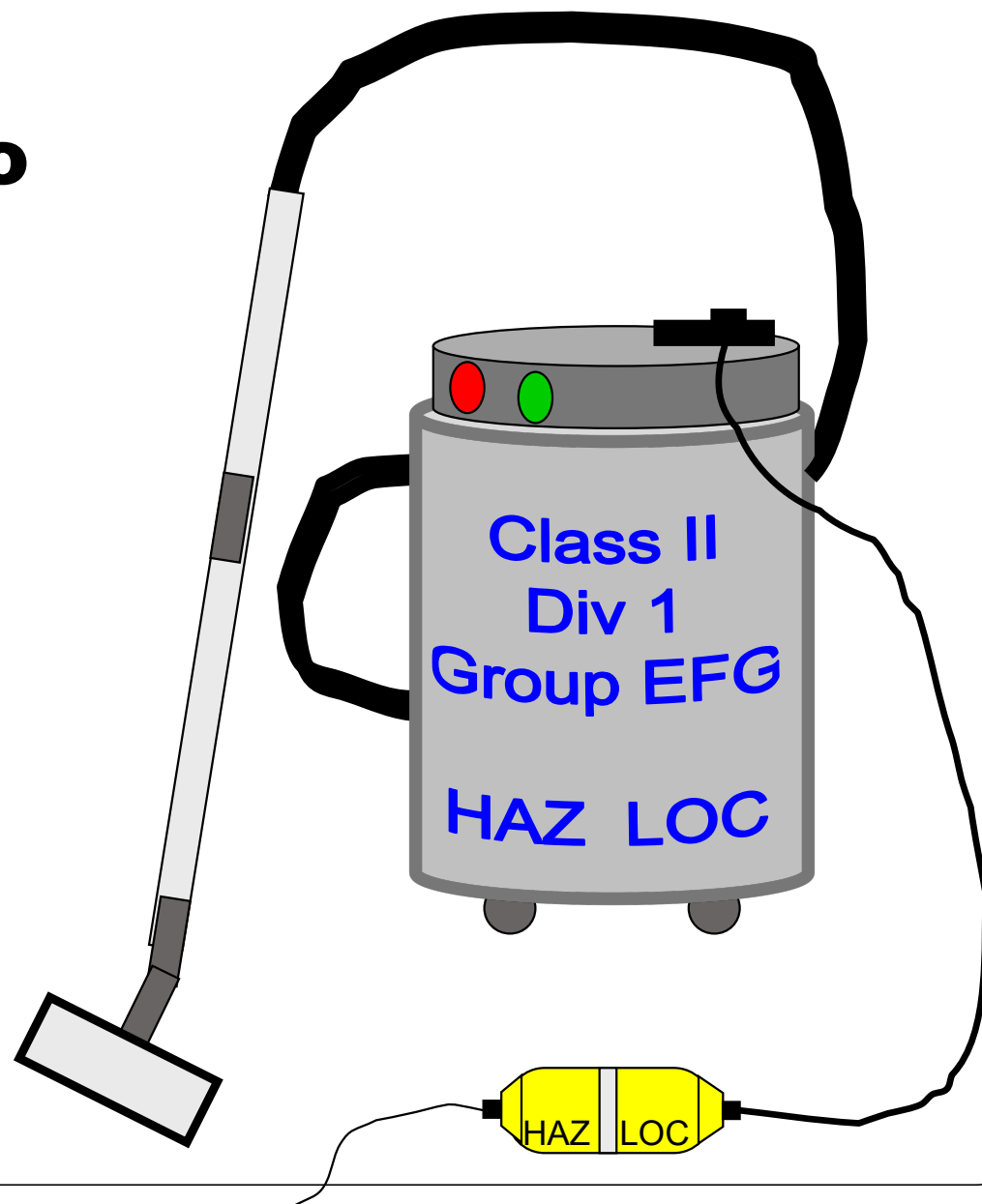
- **Provide access** to all hidden areas to permit inspection.
- **Inspect** for dust residues in open and hidden areas, at regular intervals.
- **Clean** dust residues at regular intervals.



Dust Control

NFPA 654

- Use cleaning methods that **do not generate dust clouds** if ignition sources are present.
- Only use **vacuum cleaners approved for dust collection.**



Fugitive Dust Control and Housekeeping

Dust Clouds

Surfaces shall be cleaned in a manner that minimizes the generation of dust clouds.

Vigorous sweeping or blowing down with steam or compressed air produces dust clouds and shall be permitted **only if the following requirements are met:**

RETROACTIVE



Fugitive Dust Control and Housekeeping

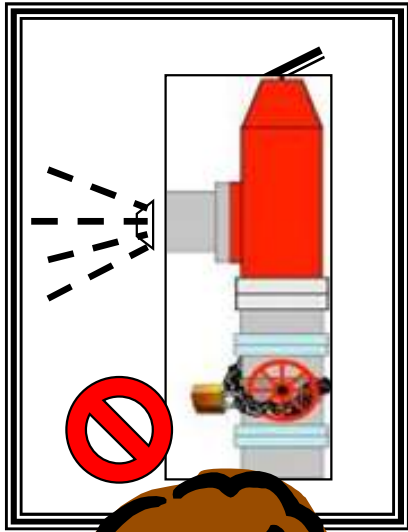
- Area and equipment **vacuumed prior to blow down.**



- Electrical power and other **sources of ignition shut down or removed** from the area.
- Only **low gauge pressure** (15 psi) steam or compressed air to be used.
- No hot surfaces** capable of igniting a dust cloud or layer.

RETROACTIVE

Dust Control



NFPA 654

- Locate **relief valves away from dust** hazard areas and
- Develop and implement a hazardous dust
 - **Inspection,**
 - **Testing,**
 - **Housekeeping,** and
 - **Written control program**

(Written with established frequency and methods).



Dust Control

- Reducing dust accumulations is a major concern for facilities that produce dust.
- A good housekeeping program depends upon a combination of methods to control dust.
- The methods used in a given facility will depend upon the type of facility and the volume of organic material handled or produced.



Dust Control Methods

- Vacuums especially in areas where dust accumulation is constant due to the job task being performed.
- Wash down procedures where hoses and water can be used to remove accumulated dust.
- Choke feeds to control the flow of grain and grain dust.
- Dust control systems such as filters or cyclones.



Recognizing Dust Hazards

- All employees should be trained in hazard recognition:
 - Conduct general facility wide appraisals of dust explosion possibilities on a periodic basis.
 - Conduct internal and external audits in order to identify potential explosion hazards.
 - Encourage a preventative attitude among employees for dust explosions.
 - Have employees and supervisors identify explosion hazards through JHAs.
 - Pay particular attention to dust collection systems and other areas not in plain view during the assessment.



U.S. Chemical Safety and Hazard Investigation Board Photo



U.S. Chemical Safety and Hazard Investigation Board Photo

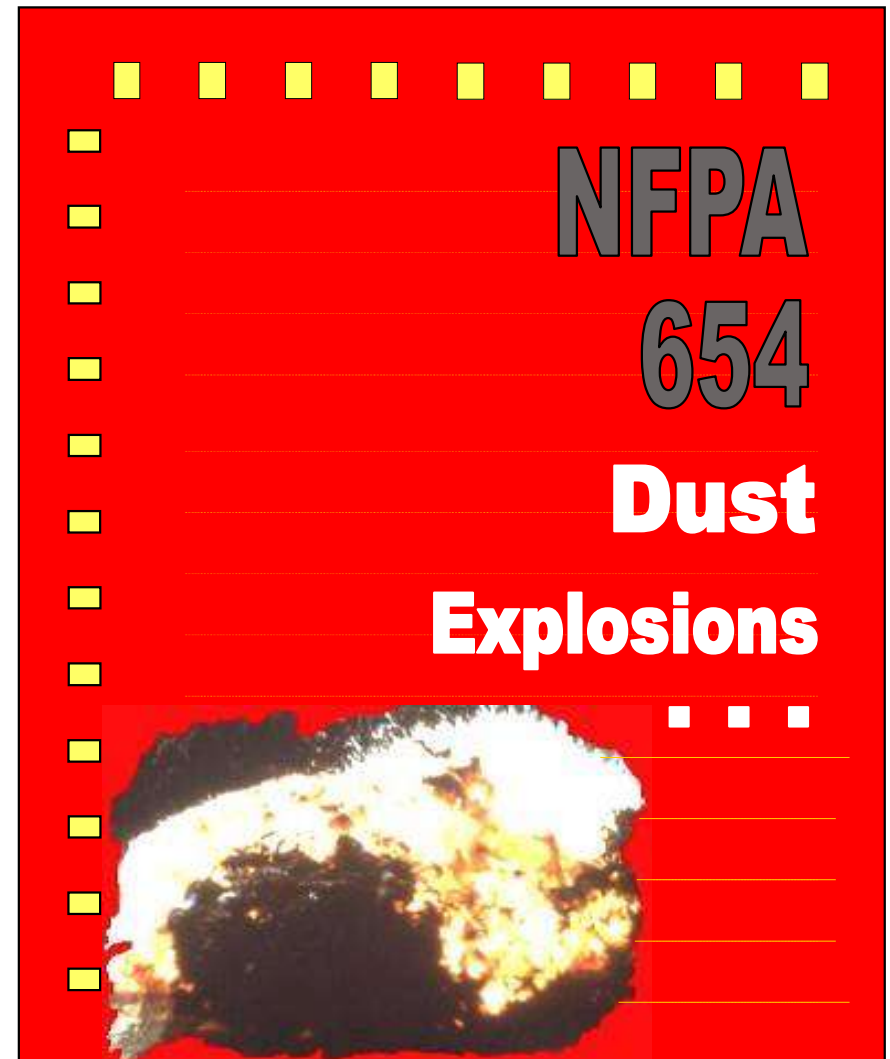
Engineering Controls

- Avoid the use of compressed air (blow down), and dry sweeping.
- Conduct workforce training and education courses.
- Limit and control potential ignition sources.
- Ensure electrical service in combustible dust areas is appropriate for hazardous (Class II) locations.



Engineering Controls

- Follow National Fire Protection Association (NFPA) standard 654.
- Ensure operations involving dusts have proper engineering design and controls.
- Maintain an effective housekeeping program.
- Establish and maintain a preventative maintenance program.



Lessons Learned

West Pharmaceutical Services, Inc.

- On January 29, 2003, a massive dust explosion at the West Pharmaceutical Services facility in Kinston, North Carolina, killed six workers and destroyed the facility.
- The explosion involved a part of the building used to compound rubber.
 - The compounding process produced a powder that was carried by air currents to the space above a suspended ceiling.
- Employees not trained on the hazards.

West Pharmaceutical



Lessons Learned

CTA Acoustics, Inc.

- On February 20, 2003, a series of dust explosions at the CTA Acoustics facility in Corbin, Kentucky, claimed the lives of seven workers, injured 37, and destroyed the manufacturing facility.
- This facility primarily made acoustic insulation for automobiles.
 - A curing oven that had been left open because of a temperature control problem likely ignited the combustible resin dust stirred up by workers cleaning the area near the oven.
- Had CTA had adhered to NFPA 654 (2000) standards for housekeeping and fire/explosion barriers, the explosions could have been prevented or minimized.

CTA Acoustics Inc.



Lessons Learned

Hayes Lemmerz International.

- On October 29, 2003, aluminum dust exploded at the Hayes Lemmerz International facility in Huntington, Indiana, killed one worker and injured several others.
 - This explosion involved equipment used to re-melt scrap aluminum
 - The scrap aluminum was chopped into small chips, pneumatically conveyed to the scrap processing area, dried, and fed into a melt furnace .
 - Transporting and drying the aluminum chips generated explosive aluminum dust, which was then pulled into a dust collector.

Hayes Lemmerz International



Lessons Learned

Safety Issues Neglected

- Facility management failed to conform to NFPA standards that would have prevented or reduced the effects of the explosions.
- Company personnel, government enforcement officials, insurance underwriters, and health and safety professionals inspecting the facilities failed to identify dust explosion hazards or recommend protective measures.
- The facilities contained unsafe accumulations of combustible dust and housekeeping was inadequate.
- Workers and managers were often unaware of dust explosion hazards.

Lessons Learned

Safety Issues Neglected

- Procedures and training to eliminate or control combustible dust hazards were inadequate.
- Previous fires and other warning events were accepted as normal, and their causes were not identified and resolved.
- Dust collectors were inadequately designed or maintained to minimize explosions.
- Process changes were made without adequately reviewing them for potential hazards.

Summary

- Dust explosions are a serious problem in American industry.
- During the past 25 years, at least 281 major combustible dust incidents were reported, that killed 119 and injured 718 workers, and destroyed many industrial facilities.
- Facilities fail to follow the widely recognized standards of good engineering practice in the NFPA's voluntary consensus standards.

Summary

Facilities do not:

- Implement appropriate engineering controls
- Perform adequate maintenance
- Implement good housekeeping practices
- Follow other measures that could have prevented the explosions
- Provide adequate hazard recognition training for employees
- Establish overall safe work practices